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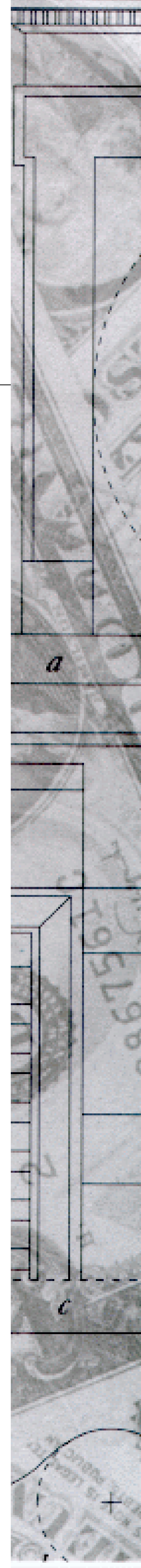

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ESTIMATING SWITCHING COSTS AND OLIGOPOLISTIC BEHAVIOR*

Moshe Kim[†] Doron Kliger[‡] Bent Vale[§]

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Abstract

We present an empirical model of firm behavior in the presence of switching costs. Customers' transition probabilities, embedded in firms' value maximization, are used in a multi-period model to derive estimable equations of a first order condition, market-share (demand), and supply equations. The novelty of the model is in its ability to extract information on both the magnitude and significance of switching costs, as well as on customers' transition probabilities, from conventionally available highly aggregated data which do not contain customer-specific information. As a matter of illustration, the model is applied to a panel data of banks, to assess the switching costs in the market for bank loans. The point estimate of the average switching cost is 4.1% which is about one third of the market average interest rate on loans. More than a quarter of the customer's added value is attributed to the lock-in phenomenon generated by theses switching costs. About a third of the average bank's market share is due to its established bank-borrower relationship.

Keywords: switching costs, transition probability, banking.
JEL Classification: L13, G21

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1. Introduction

Switching costs are costs induced when economic agents change their suppliers. As such, ex-ante homogeneous products become ex-post heterogeneous. These costs originate from a host of reasons, economic as well as psychological. Various addictions, cognitive dissonance problems and similar phenomena are just a few examples for the psychological origins of switching costs. Intertemporal product and service compatibility, network externalities, informational investment in business relationships are few examples of the economic origins of switching costs. From the theoretical perspective, customer switching costs confer market power on firms. Thus, firms may face a trade off between charging low prices to attract customers and lock them in, and high prices to extract supra normal rents from its already locked-in customers. The vast theoretical literature on switching costs is summarized in Klemperer (1995).[1] Studies dealing with this phenomenon attempt to gain insight into the main issues of industrial organization such as entry deterrence, and the command over supra-normal rents. Shapiro and Varian (1998), in their recently published book, provide numerous examples of the impact of switching costs on market behavior.

The available empirical studies investigate the effect of switching costs on prices and market power. Ausubel (1991) provides some information that switching costs

[1] Contributions to the theory of switching costs are as early as Selten (1965) and von Weizsäcker (1984). Klemperer (1985) examines a two-period differentiated-product duopoly in which customers are partially "locked-in" by switching costs that they face in the second period, which results in higher prices in both periods compared to the non switching cost case. Klemperer (1987) introduces switching costs in order to explain the emphasis placed on market share as a goal of corporate strategy. Beggs and Klemperer (1992) show how switching costs make the market more attractive to a new entrant and Klemperer (1987), examines how the threat of new entry affects incumbent's behavior thereby providing an explanation of limit pricing behavior. Chen and Rosenthal (1996) consider a stochastic game with slowly changing customer loyalties resulting in Markov perfect equilibrium. Padilla (1992) develops a model resulting in ex ante identical firms having ex post asymmetric market shares and in his Padilla (1995) paper he shows that in an infinite-horizon model with stationary Markovian strategies, the strength of copetition is relaxed. Caminal and Matutes (1990) consider a model with endogenous switching costs and show that in the second period of the game firms discriminate against newcomers. Cabral and Greenstein (1990) claim that there may be economic merit to ignoring switching costs because the increased competitiveness in response to bidding parity can outweigh the costs of switching between suppliers.

may explain the high interest rates on credit card balances, and Stango (1998), using variables related to switching, finds that switching costs are an important influence on pricing in that market. Knittel (1997), using some proxies for switching costs, shows that these have provided long distance telephone carriers with market power. Sharpe (1997) finds that (banking) retail deposit-rates are positively affected by a proxy of switching costs. Dahlby and West (1986) support the effect of costly search on price dispersion in the liability insurance, and Schlesinger and von der Schulenburg (1993) document a similar result for the auto insurance. Greenstein (1993) estimates the probability of "lock-in" in commercial mainframe computer systems acquired by federal agencies. His results may indirectly confirm the existence of the switching costs for that sector but no quantification of the magnitude of switching costs is attempted. Another interesting empirical example is that of Borenstein (1991) for the gasoline market where price discrimination is possible due to differences in the willingness of customers to switch stations. In a recent article, Shum (1999) measures the effect of advertising on habit persistence in the purchasing behavior of various brands of Cereals. Shum finds that advertising encourages switching behavior at the household level. His main empirical question however, concerns how advertising affects brand substitutability thereby enhancing competitive conduct and lowering margins, and not the measurement of switching costs.

Although the aforementioned empirical studies do point to the importance of switching costs in the determination of conduct and how it may be affected by various firms' policies, we generally lack information on the magnitude and significance of switching costs. Whether switching costs is an important empirical phenomenon probably depends on the specific environment, industry, product type, and time period. One possible reason for the lack of empirical documentation on the magnitude and significance of switching costs is that the necessary micro data on individual-level transitions are rarely, if ever, available to researchers.[2] Hence, the estimation of switching costs, which are unobservable, cannot be accomplished using discrete choice models.[3] In the context of estimating switching costs, the unobservables are individual customers' purchase decision histories. More specifically, we lack information on the identity of customers' previous suppliers.

The task of the present research is to complement the existing theoretical models with an empirical model capable of highlighting the process of customer's switching behavior when customer-specific data is absent, and then embed it in a general behavioral model of the firm. As a matter of illustration, we estimate the magnitude and significance of switching costs in the market for bank loans and empirically investigate various counterfactuals related to bank and customer behavior in this market.[4] It should be noted that from an empirical perspective, switching costs may perhaps be more pronounced where such costs contribute to, and may result from, long-term relationships and repeated contacts among firms and their customers. In such cases customers' switching among suppliers may entail not only pure psychological costs but rather costs related to the loss of capitalized value of relationships previously established. As such, bank loans may provide a natural setting for the investigation of the magnitude and significance of switching costs. The banking sector is a major sector in the economy in which switching costs seem to be prevalent due to information asymmetries. A high quality borrower that tries to switch to a competing (uninformed) bank may be pooled with low-quality borrowers and thus may encounter unfavorable conditions (Sharpe (1990), von Thadden (1998)).

[2] There exist quite rich data sets on individual transactions pertaining to grocery-scanner, airline-reservation, and telephone-subscription data. However, even these data sets do not provide crucial information as to customer-specific purchase histories such as previous suppliers. Shum (1999), e.g., encounters the problem of having to use aggregate (national) data for his advertising expenditure which is the major variable in his model. Moreover, all these data sets are just (small) samples which may not represent the industry at large. This shortcoming may be crucial when specifying models of oligopolistic interaction among firms since the number of (relevant) firms in the industry (partially) determines pricing behavior.

[3] See Anderson, De Palma, and Thisse (1989), and Berry, Levinsohn, and Pakes (1995) for these types of models.

[4] Our data set includes *all* banks in the industry, see section 4.1.

This phenomenon (also known as the 'lemon' problem) may be exacerbated during periods of systemic wide banking problems or during rescission periods. Thus, a switch between suppliers in the market for loans may entail direct costs of closing an account with one bank and opening it elsewhere, as well as the unobserved, and perhaps the most significant costs associated with the foregone capitalized value of (previously established) long term customer-bank relationship. Indeed, the extensive discussion in recent literature about the importance of "relationship banking" and its significant effect on borrowers' values, (James (1987), Vale (1993), and Petersen and Rajan (1994)) may point to the existence of severe switching costs in this sector.[5]

The paper is organized in as follows: in section 2 we describe the model, and section 3 describes the empirical methodology. Section 4 describes the data used, and section 5 provides the results and some counterfactuals. Section 6 concludes the paper.

2. A Model of Competition with Switching Costs

The model presented in this section emanates from theoretical investigation of the effect of customer switching costs on market conduct (see Klemperer (1987)). While the available theoretical models provide insight into firm and customer behavior, they generally require adjustment for empirical application. Moreover, equations emanating from theory require information regarding switches. Information on switches, however, does not exist in aggregate data. The proposed model is aimed at providing behavioral equations that fit for estimation, while remaining in line with, and in the spirit of, known theoretical results.

[5] The importance of the relationship depends on the length of the interaction between the bank and its customer. Relationship may evolve in cases where complete contracts are not feasible, but long term interaction is mutually beneficial. Thus, breaking up a relationship and forming a new one may entail severe switching costs. Also, the number of relationships may affect the value of relationships lost when switching suppliers. However, as found by Ongena and Smith (1999), the mean number of relationships is 1.37 and the median is 1.0. Thus, we expect quite a substantial informational loss due to switching.

Our major effort is aimed at formulating a model which is feasible for estimation given the highly aggregated nature of the data which do not contain information on customer-specific transition histories. An additional attractive property of our model, vis-a-vis existing theoretical models, is that our model *allows* customers to switch between firms at any period. In most theoretical models switching-costs serve as a threshold which cause customers *not to switch* between firms whereas casual empirical observation indicates to the contrary.[6]

2.1. The Model's Framework

Consider an oligopoly of n firms which compete in a multiple-stage price (Bertrand) competition. The good sold by these firms is unstorable. To focus on customers' decisions from which firm to purchase the good, the customers are assumed to have an inelastic demand.[7] Specifically, each customer purchases a quantity of the good in each one of an infinitely many discrete periods.[8] The customer optimizes her utility by deciding from which firm to purchase, given the prices charged by the firms. When comparing the charged prices, the customer keeps in mind that switching between firms is costly. Formally, we add the switching costs to the prices charged by firms the customer did not buy from in the previous period. The customer behavior described here yields probabilities of switching between firms. We denote these probabilities as *transition probabilities*. The transition probabilities are functions of the prices and switching costs. Aggregation of the transition probabilities yields the demand faced by each firm.

2.2. Transition-Probability Induced Demand

When choosing from which firm to purchase the good, the customer compares the prices charged by the various firms. We model the customer's purchase decision in

[6] See von Thadden (1998) for a theoretical analysis showing switching of customers in equilibrium in the context of bank loans.

[7] This is often assumed in the literature, e.g., Caminal and Matutes (1990).

[8] We allow the demanded quantity to change at an exogenously determined rate.

terms of the probabilities of purchasing the good from the different firms. Modeling the purchase decision in probabilities allows customer heterogeneity in the model: when aggregating over the customers, the probability of purchasing from a specific firm approaches the proportion of customers who decide to buy from that firm. This formulation also facilitates the empirical observation that customers occasionally chose to switch to a firm charging a higher price. In fact, as long as the transition probabilities are not null or unity, some customers switch to and from each firm. To accommodate the possible presence of switching costs, we condition these probabilities on the customer's previous purchase decisions, i.e., we use *transition probabilities*. For tractability, we assume purchase probabilities are Markovian. Switching costs enter the model in the following way: for any possible purchase decision that entails switching (i.e., for purchasing from a firm the customer did not purchase from in the previous period), the cost of switching is added to the price charged by the firm. The probability that a customer who bought in period $t-1$ from firm i will retain her purchase in the subsequent period with that firm is denoted by $\Pr_{i\to i,t}$. Similarly, the probability that a customer who previously purchased from firm j will switch to purchase from firm i in the subsequent period is denoted by $\Pr_{j\to i,t}$. Formally, the transition probabilities are functions of the price charged by the firm, $p_{i,t}$, and of the alternative prices offered by firm i's rivals, the $(n-1)$ vector $\mathbf{p}_{iR,t}$.[9] The switching costs borne by the customer in case of switching to purchase from a firm she did not purchase from in the previous period are denoted by s.[10] The probability of continuing to purchase from the same firm is, therefore:

$$\Pr_{i\to i,t} = f\left\{p_{i,t}, \mathbf{p}_{iR,t} + \mathbf{s}\right\} \tag{2.1}$$

[9] Throughout, we use bold letters to denote vectors.

[10] Actually, switching costs are likely to differ among customers. Therefore, s should be interpreted as the *mean* switching cost. Customer-specific deviations from within-firm averages are captured by the slope of the transition probability function, while the variation in the firm-mean of switching costs is captured by the level of the function.

where $\mathbf{s}$ is a vector of switching costs, equals the scalar s multiplied by an $(n-1)$ unity vector: $\mathbf{s} \equiv s \cdot I$.

The probability of switching to firm i from a *rival* firm is formulated as follows: If a customer of a rival firm j switches to *any other* firm (either to firm i, or to one of i's rivals), she bears the cost of switching. Thus, the (conditional) probability of switching from a rival firm j to firm i is:

$$\Pr_{j \to i,t} = f\left\{p_{i,t} + s, \mathbf{p}_{iR,t} + \mathbf{s}_j\right\} \tag{2.2}$$

where $\mathbf{s}_j$ is an $(n-1)$ vector of switching costs in which each of the elements equals s, except for the j^{th} element, which is zero. In aggregate data, transitions are not observed. We thus have to uncondition customers' behavior. The resulting probability of switching to purchase from firm i *unconditional on the rival's identity* is, therefore:

$$\Pr_{iR \to i,t} = \sum_{j \neq i} \left(f\left\{p_{i,t} + s, \mathbf{p}_{iR,t} + \mathbf{s}_j\right\} \cdot \frac{y_{j,t-1}}{\sum_{k \neq i} y_{k,t-1}} \right) \tag{2.3}$$

where $\Pr_{iR \to i,t}$ is the probability that a rivals' customer will switch to purchase from firm i. We denote firm j's time $t-1$ output by $y_{j,t-1}$. Thus, $y_{j,t-1}/\sum_{k \neq i} y_{k,t-1}$ is the probability that a *randomly selected* rival's customer is one who previously purchased from firm j.

The higher (lower) the relative price charged by firm i, the lower (higher) the probability that any customer will purchase from it. Thus, the partial derivatives of (2.1) and (2.3) should have the following signs:

$$\frac{\partial \Pr_{i \to i,t}}{\partial p_{i,t}} < 0; \qquad \frac{\partial \Pr_{i \to i,t}}{\partial \mathbf{p}_{iR,t}} > 0, \tag{2.4}$$

and:

$$\frac{\partial \Pr_{iR \to i,t}}{\partial p_{i,t}} < 0; \qquad \frac{\partial \Pr_{iR \to i,t}}{\partial \mathbf{p}_{iR,t}} > 0. \tag{2.5}$$

The total demand faced by firm i at time t, $y_{i,t}$, depends on its own output in the former period, as well as on the previous output of its rivals (the "state" variables), and on the transition probabilities, which are functions of the current prices and the switching costs:

$$y_{i,t} = y_{i,t-1} \Pr_{i \to i,t} + y_{iR,t-1} \Pr_{iR \to i,t}. \tag{2.6}$$

The first term in the right hand side of (2.6) approximates the number of the firm's customers that choose to continue purchasing from it. This is because applying the law of large numbers, $\Pr_{i \to i,t}$ approaches the *proportion* of firm i's "loyal" customers. Similarly, $\Pr_{iR \to i,t}$ is the proportion of new customers out of the rivals' customer base, making the second term in the right hand side of (2.6) approximate the number of the rivals' customers that choose to switch to purchase from firm i.[11] Notice that $y_{i,t}$ is computed using information on firms' customer base, *without having to identify customer-specific actual (unobserved) transition decisions.*

To allow customers to change the purchased quantity over time, we multiply the demand faced by the firm by the market growth rate:

$$y_{i,t} = \left(y_{i,t-1} \Pr_{i \to i,t} + y_{iR,t-1} \Pr_{iR \to i,t} \right) g_t \tag{2.7}$$

where g_t is the market growth rate, $g_t \equiv \Sigma y_{i,t} / \Sigma y_{i,t-1}$. We assume the market growth rate is exogenous.[12]

2.3. Approximating the Demand

If data on *actual* customer decisions were available, a natural structure to impose on the transition probabilities would have been of a logit type. However, such data are rarely available. Aggregate data (a panel of quantities and prices) contain the information on *net* output changes only. Any net output change could result from numerous combinations of customer- arrivals and departures. Moreover, even if gross output changes would have been known, the application of logit models would

[11] Since we would like to focus on customers' *transition probabilities* among firms, it is assumed that the number of customers is fixed. That is, we model switching behavior for any given level of aggregate demand in each period. Aggregate demand, however, is allowed to change over time.

[12] Due to data limitations, we are forced to assume the industry's growth rate is exogenous. This assumption is quite reasonable in our data set (see data section, 4.1).

require customer-specific information. Henceforth, we provide a setup in which the demand faced by firms is a function of *gross* output changes. To obtain this setup, we apply a first-order (linear) approximation of the transition probabilities. Linearity makes the transition probabilities functions of the price charged by the firm, $p_{i,t}$, the average price charged by the rival firms, $\bar{p}_{iR,t}$, and the cost of switching between firms, s:

$$\Pr_{i\to i,t} = \alpha_o^i + \alpha_1 p_{i,t} + \alpha_2 \left(\bar{p}_{iR,t} + s\right) \tag{2.8}$$

and:

$$\Pr_{iR\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} + s\right) + \alpha_2 \left(\bar{p}_{iR,t} + \frac{n-2}{n-1}s\right) \tag{2.9}$$

where α_o^i are firm-specific intercepts which capture firm heterogeneity.[13]

It is important to emphasize here that (2.9) is not a function of a specific rival j, and thus, it is also the transition probability of a *randomly-selected rivals' customer*.

The transition probabilities (2.8) and (2.9) remain valid for cases where the econometrician observes only a noisy version of the prices. An example is prices unadjusted for output characteristics.[14]

As discussed in the previous section, the transition probabilities should be decreasing in the firm's own price and increasing in the average of the rivals' prices. Thus, the partial derivatives of (2.8) and (2.9), respectively, are expected to have the following signs:

$$\frac{\partial \Pr_{i\to i,t}}{\partial p_{i,t}} = \alpha_1 < 0; \qquad \frac{\partial \Pr_{i\to i,t}}{\partial \bar{p}_{iR,t}} = \alpha_2 > 0; \tag{2.10}$$

[13] The derivation of equation (2.9) is as follows. The transition probability from a rival firm j to firm i is $\Pr_{j\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} + s\right) + \alpha_2^* I' \left(\mathbf{p}_{iR,t} + \mathbf{s}_j\right)$ where $\mathbf{s}_j$ is an $(n-1)$ vector of switching costs, in which each of the elements equals s, except for the j^{th} element, which is zero. This can be written as $\Pr_{j\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} + s\right) + \alpha_2^* \left(\sum_{j\neq i} p_{j,t} + (n-2)\, s\right)$, or, for $\alpha_2^* = \frac{\alpha_2}{n-1}$, $\Pr_{j\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} + s\right) + \alpha_2 \left(\bar{p}_{iR,t} + \frac{n-2}{n-1}s\right)$. This equation is not a function of j, thus, it is also the transition probability of a *randomly-selected* rivals' customer: $\Pr_{iR\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} + s\right) + \alpha_2 \left(\bar{p}_{iR,t} + \frac{n-2}{n-1}s\right)$.

[14] The validity of the transition probabilities for this case is delegated to Appendix A.

and:

$$\frac{\partial \Pr_{iR\to i,t}}{\partial p_{i,t}} = \alpha_1 < 0 \ ; \qquad \frac{\partial \Pr_{iR\to i,t}}{\partial \bar{p}_{iR,t}} = \alpha_2 > 0. \tag{2.11}$$

Under symmetry, for a given total demand, a small increase in $p_{i,t}$ should have the same effect on the transition probabilities as that of a decrease of the same magnitude in rivals' average price, $\bar{p}_{iR,t}$. Thus, we restrict $\alpha_2 = -\alpha_1$. The resulting transition probabilities, then, are:

$$\Pr_{i\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} - \bar{p}_{iR,t} - s\right) \tag{2.12}$$

and:

$$\Pr_{iR\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} - \bar{p}_{iR,t} + \frac{s}{n-1}\right). \tag{2.13}$$

As is apparent in equations (2.12) and (2.13), the presence of switching costs works in favor, as well as against, the firm: the higher s, the higher the proportion of the firm's customers that will choose not to switch to other firms ($\partial \Pr_{i\to i,t} / \partial s = -\alpha_1 > 0$), but the lower the proportion of the rivals' customers that will choose not to switch to the firm ($\partial \Pr_{iR\to i,t} / \partial s = \alpha_1 / (n-1) < 0$).

Using the linear transition probabilities, we are able to compute the firm's demand. Substituting (2.12) and (2.13) into the output equation (2.7) and dividing by the time t market demand yields the firm's time t market-share, $\sigma_{i,t}$:

$$\sigma_{i,t} = -\sigma_{i,t-1}\frac{n}{n-1}s\alpha_1 + \alpha_o^i + \alpha_1 \left(p_{i,t} - \bar{p}_{iR,t} + \frac{s}{n-1}\right). \tag{2.14}$$

Thus, the period t market share is a function of the preceding period's market share, the number of competing firms, the switching costs, firms' heterogeneity (as captured by the fixed effects), and rivals' prices.

The part of the current market share induced by the time $t-1$ market share is represented by:[15]

$$\left(-\sigma_{i,t-1}\frac{n}{n-1}s\alpha_1\right) > 0. \tag{2.15}$$

[15] Recall that α_1 is negative.

We term the effect of the $t-1$ market share on the firm's current market share as the *lock-in effect*:

$$\frac{\partial \sigma_{i,t}}{\partial \sigma_{i,t-1}} = -\frac{n}{n-1} s\alpha_1 > 0. \tag{2.16}$$

The contribution of the existing (time $t-1$) market-share to the current market-share is increasing in the magnitude of switching-costs,

$$\frac{\partial \left(\frac{\partial \sigma_{i,t}}{\partial \sigma_{i,t-1}} \right)}{\partial s} = -\frac{n}{n-1} \alpha_1 > 0. \tag{2.17}$$

We term the effect of switching costs on market shares as the *switching-cost effect:*

$$\frac{\partial \sigma_{i,t}}{\partial s} = \left(\frac{1}{n} - \sigma_{i,t-1} \right) \frac{n}{n-1} \alpha_1 \left\{ \begin{array}{ll} < 0 & if\ \sigma_{i,t-1} < 1/n \\ > 0 & if\ \sigma_{i,t-1} > 1/n \end{array} \right. . \tag{2.18}$$

The switching costs effect works in favor of larger-than-average firms, and against smaller-than-average firms. The intuition behind this effect is straightforward. The larger the firm's market share, the more customers are locked-in with it, and the less customers are "locked out" of the firm.

2.4. Firms' Present-Value Maximization

At any point in time (denoted by τ), the firm maximizes the present value of its profits:

$$V_{i,\tau} = \sum_{t=\tau}^{\infty} \delta^{t-\tau} \pi_{i,t} \tag{2.19}$$

where δ is the one-period discount factor, $\pi_{i,t}$ is the firm's time t profit, i.e.,

$$\pi_{i,t} \equiv y_{i,t} \cdot p_{i,t} - c_{i,t} \tag{2.20}$$

and the firm's technology is specified by a cost function, defined on its output, $y_{i,t}$, and on a vector of input prices, $\mathbf{w}_{i,t}$:

$$c_{i,t} = c \left\{ \mathbf{w}_{i,t}, y_{i,t} \right\}. \tag{2.21}$$

A necessary condition for the firm's optimal (present value maximizing) behavior is setting the time τ price, $p_{i,\tau}$, such that the derivative of (2.19) w.r.t. this price is zero:[16]

$$\frac{\partial V_{i,\tau}}{\partial p_{i,\tau}} = \sum_{t=\tau}^{\infty} \delta^{t-\tau} \frac{\partial \pi_{i,t}}{\partial p_{i,\tau}} = 0. \tag{2.22}$$

Notice that the time τ price affects not only the time τ profit, $\pi_{i,\tau}$, but also the profits in subsequent periods. The reason for this is that any period's output affects the demand in the period that follows.[17] Inserting the time t profit, (2.20), (2.22) becomes:

$$\begin{aligned} \frac{\partial V_{i,\tau}}{\partial p_{i,\tau}} &= \sum_{t=\tau}^{\infty} \delta^{t-\tau} \frac{\partial \left(y_{i,t} \cdot p_{i,t} - c_{i,t} \right)}{\partial p_{i,\tau}} \\ &= y_{i,\tau} + \sum_{t=\tau}^{\infty} \delta^{t-\tau} \left(\frac{\partial y_{i,t}}{\partial p_{i,\tau}} p_{i,t} - \frac{\partial c_{i,t}}{\partial y_{i,t}} \frac{\partial y_{i,t}}{\partial p_{i,\tau}} \right) = 0 \end{aligned} \tag{2.23}$$

or:

$$\frac{\partial V_{i,\tau}}{\partial p_{i,\tau}} = y_{i,\tau} + \sum_{t=\tau}^{\infty} \delta^{t-\tau} \left(p_{i,t} - \frac{\partial c_{i,t}}{\partial y_{i,t}} \right) \frac{\partial y_{i,t}}{\partial p_{i,\tau}} = 0 \tag{2.24}$$

where the effect of the current price on the quantity demanded k periods ahead is:

$$\frac{\partial y_{i,\tau+k}}{\partial p_{i,\tau}} = \frac{\partial y_{i,\tau+k}}{\partial y_{i,\tau+k-1}} \cdot \frac{\partial y_{i,\tau+k-1}}{\partial y_{i,\tau+k-2}} \cdot ... \cdot \frac{\partial y_{i,\tau}}{\partial p_{i,\tau}} \quad for\ k = t - \tau. \tag{2.25}$$

For similar arguments, another requirement for the firm's optimal behavior is that the derivative of (2.19) w.r.t. the time $\tau + 1$ price, $p_{i,\tau+1}$, is zero along the optimal path:

$$\frac{\partial V_{i,\tau}}{\partial p_{i,\tau+1}} = y_{i,\tau+1} + \sum_{t=\tau}^{\infty} \delta^{t-\tau+1} \left(p_{i,t} - \frac{\partial c_{i,t}}{\partial y_{i,t}} \right) \frac{\partial y_{i,t}}{\partial p_{i,\tau+1}} = 0 \tag{2.26}$$

where:

$$\frac{\partial y_{i,\tau+k}}{\partial p_{i,\tau+1}} = \frac{\partial y_{i,\tau+k}}{\partial y_{i,\tau+k-1}} \cdot \frac{\partial y_{i,\tau+k-1}}{\partial y_{i,\tau+k-2}} \cdot ... \cdot \frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau+1}} \quad for\ k = t - \tau. \tag{2.27}$$

[16] The second-order condition for present value maximization is satisfied because (2.19) is concave: The present value function is a sum of the concave per-period profits, $\pi_{i,t}$, and all future demanded quantities ($y_{i,\tau+k} \quad k > 1, 2, ...$) may be expressed as linear functions of the current demand, $y_{i,t}$.

[17] This is easily seen by iterative substitution of equation (2.7) which describes the demand faced by the firm.

Since both (2.24) and (2.26) are necessary conditions, any linear combination of them should hold as well. Thus, for any $dp_{i,\tau}$ and $dp_{i,\tau+1}$, the following should hold:

$$\frac{\partial V_{i,\tau}}{\partial p_{i,\tau}} dp_{i,\tau} + \frac{\partial V_{i,\tau}}{\partial p_{i,\tau+1}} dp_{i,\tau+1} = 0. \tag{2.28}$$

In particular, let us choose a pair of price differentials $dp_{i,\tau}$ and $dp_{i,\tau+1}$ that keeps $y_{i,\tau+1}$ constant:

$$\frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau}} dp_{i,\tau} + \frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau+1}} dp_{i,\tau+1} = 0 \tag{2.29}$$

or:

$$dp_{i,\tau+1} = -\frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau}} \Bigg/ \frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau+1}} dp_{i,\tau} \, . \tag{2.30}$$

Substituting $\frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau}} = -y_{\tau-1}\alpha_1 \frac{n}{n-1}\alpha_1 s g_\tau g_{\tau+1}$ and $\frac{\partial y_{i,\tau+1}}{\partial p_{i,\tau+1}} = y_{\tau-1}\alpha_1 g_\tau g_{\tau+1}$ into (2.30), we obtain the time $\tau+1$ price-differential in terms of the time τ price-differential, for a constant $y_{i,\tau+1}$:[18]

$$dp_{i,\tau+1} = dp_{i,\tau} \frac{n}{n-1} \alpha_1 s. \tag{2.31}$$

Since $y_{i,\tau+1}$ is unchanged, condition (2.28) becomes:[19]

$$\left(\frac{\partial \pi_{i,\tau}}{\partial p_{i,\tau}} + \delta \frac{\partial \pi_{i,\tau+1}}{\partial p_{i,\tau}} \right) dp_{i,\tau} + \delta \frac{\partial \pi_{i,\tau+1}}{\partial p_{i,\tau+1}} dp_{i,\tau+1} = 0. \tag{2.32}$$

Furthermore, as $y_{i,\tau+1}$ is constant, (2.32) becomes:

$$\frac{\partial \pi_{i,\tau}}{\partial p_{i,\tau}} dp_{i,\tau} + \delta \cdot y_{i,\tau+1} dp_{i,\tau+1} = 0. \tag{2.33}$$

Inserting (2.31) into (2.33) and rearranging:

$$\frac{\partial \pi_{i,\tau}}{\partial p_{i,\tau}} + \delta \cdot y_{i,\tau+1} \frac{n}{n-1} \alpha_1 s = 0. \tag{2.34}$$

Writing the derivative of the time τ profit explicitly, yields:

$$y_{i,\tau} + \left(p_{i,\tau} - \frac{\partial c_{i,\tau}}{\partial y_{i,\tau}} \right) \frac{\partial y_{i,\tau}}{\partial p_{i,\tau}} + \delta y_{i,\tau+1} \frac{n}{n-1} \alpha_1 s = 0. \tag{2.35}$$

[18]For a derivation of the output derivatives refer to Appendix C.

[19]The terms in (2.28) containing the derivatives of $\pi_{i,\tau+2}$ and onwards disappear as they all are, ultimately, products of the change in $y_{i,\tau+1}$, which is zero.

As $\frac{\partial y_{i,\tau}}{\partial p_{i,\tau}} = y_{\tau-1}\alpha_1 g_\tau$, (2.35) can be expressed as:

$$pcm_{i,t} = -\delta \cdot \sigma_{i,t+1}\frac{n}{n-1}sg_{t+1} - \frac{\sigma_{i,t}}{\alpha_1}. \tag{2.36}$$

where $pcm_{i,t} \equiv p_{i,t} - mc_{i,t}$ is the period t price-cost margin. Equation (2.36) captures the relation between the price-cost margin, the market shares, and the switching costs. To provide some intuition for this first order condition, notice that the first term represents the benefits to the firm from capturing customers in period t that will be "locked-in" in future periods. The larger this benefit is (a higher s or g_{t+1}), the lower will be the optimal period t price cost margin in the attempt to capture customers. The second term represents the current period oligopoly power of the firm; the larger is the current market share the larger will be the price cost margin. Notice that the existence of switching costs results in a larger market shares and hence more oligopoly power for larger than average firms (cf. equation (2.18)). In the absence of switching costs the optimization problem reduces to the conventional case of a one period oligopoly,

$$pcm_{i,t} = -\frac{\sigma_{i,t}}{\alpha_1} \tag{2.37}$$

where as far as switching costs exist, the firms' pricing decision is intrinsically intertemporal.

An increase in the discount factor δ (i.e., a decrease in the discount rate) has the same effect on prices as an increase in the growth rate of aggregate output g_{t+1}.[20] A higher growth rate increases the relative importance of future profits, hence making it more profitable for firms to lower current prices and lock in a larger market share.[21]

The firm's optimization may shed some light on the value of customer "lock-in". Define the marginal value of a locked-in customer, $mvl_{i,t}$, as the marginal increase in the firm's present value due to an additional locked-in customer ($\partial V_{i,t}/\partial y_{i,t}$), beyond

[20]This property is in line with the prediction of Beggs and Klemperer (1992)

[21]Slade (1991) provides empirical support for that effect for the metals markets.

the increase in profits generated by the current sales to that customer. This implies that:

$$\frac{\partial V_{i,t}}{\partial y_{i,t}} = \frac{\partial \pi_{i,t}}{\partial y_{i,t}} + mvl_{i,t}. \tag{2.38}$$

For constant market size in steady state, the proportion of $mvl_{i,t}$ in $\partial V_{i,t}/\partial y_{i,t}$ equals the "lock-in" effect (defined in (2.16)), discounted for one period:[22]

$$\frac{mvl_{i,t}}{\partial V_{i,t}/\partial y_{i,t}} = -\delta\frac{n}{n-1}s\alpha_1. \tag{2.39}$$

This is so because $mvl_{i,t}$ equals the discounted marginal increase in the firm's present value due to an additional locked-in customer in the subsequent period:

$$mvl_{i,t} = \delta\frac{\partial V_{i,t+1}}{\partial y_{i,t}} = \delta\frac{\partial V_{i,t+1}}{\partial y_{i,t+1}}\frac{\partial y_{i,t+1}}{\partial y_{i,t}}, \tag{2.40}$$

implying that:

$$\frac{\partial V_{i,t}}{\partial y_{i,t}} = \frac{\partial \pi_{i,t}}{\partial y_{i,t}} + \delta\frac{\partial V_{i,t+1}}{\partial y_{i,t}}. \tag{2.41}$$

In this case, $\partial V_{i,t+1}/\partial y_{i,t+1} \approx \partial V_{i,t}/\partial y_{i,t}$, since (for $g_t = 1$, $\forall t$) $y_{i,t+1} \approx y_{i,t}$. Solving for $\partial V_{i,t}/\partial y_{i,t}$ yields:

$$\frac{\partial V_{i,t}}{\partial y_{i,t}} = \frac{\partial \pi_{i,t}}{\partial y_{i,t}}\left(1-\delta\frac{n}{n-1}s\alpha_1\right)^{-1} \tag{2.42}$$

or, as a proportion of the added value of an additional customer,

$$\frac{\partial \pi_{i,t}/\partial y_{i,t}}{\partial V_{i,t}/\partial y_{i,t}} = \left(1-\delta\frac{n}{n-1}s\alpha_1\right). \tag{2.43}$$

Using (2.38), the contribution of "lock-in" as a proportion of the added value is:

$$\frac{mvl_{i,t}}{\partial V_{i,t}/\partial y_{i,t}} = 1 - \frac{\partial \pi_{i,t}/\partial y_{i,t}}{\partial V_{i,t}/\partial y_{i,t}} = -\delta\frac{n}{n-1}s\alpha_1. \tag{2.44}$$

[22] We believe constant market size is a reasonable approximation. See data section.

3. Empirical Methodology

The model presented in Section 2 yields the following equations:

(i) the first order condition (2.36):

$$pcm_{i,t} = -\delta\sigma_{i,t+1}\frac{n}{n-1}sg_{t+1} - \frac{\sigma_{i,t}}{\alpha_1}, \tag{3.1}$$

(ii) the market share equation (2.14):

$$\sigma_{i,t} = -\sigma_{i,t-1}\frac{n}{n-1}s\alpha_1 + \alpha_o^i + \alpha_1\left(p_{i,t} - \bar{p}_{iR,t} + \frac{s}{n-1}\right). \tag{3.2}$$

In order to estimate the model we search for the parameter values that best fit the data.[23] To eliminate the numerous fixed effects (α_o^i), the market share equation (3.2) is first-differenced. To obtain the price-cost margin in (3.1), we estimate the marginal cost implied by the system of cost function and input share equations (see Appendix B).[24] The system of equations (including the cost structure) is estimated simultaneously using non-linear 3SLS. The endogenous variables in the model $\sigma_{i,t}$, $\sigma_{i,t+1}$, the time differences of the prices and of the market shares as well as the output, are instrumented by the lagged output, lagged number of branches and various lags of the market shares.

A positive s is our basic indication for the existence of customer switching costs in the market for bank loans. We interpret the data as providing significant evidence for the existence of switching costs if s turns out significantly positive. Futhermore, since demand should be downward sloping, the validity of the model is indicated by the sign of α_1. The demand curve is downward sloping if and only if α_1 is negative.

3.1. Details

In the estimation procedure, we have to make sure the transition probabilities are within the $[0, 1]$ interval. First, we show here the range of switching costs for which

[23] We use a panel data of the entire Norwegian banking sector for the period 1988-96. For details see Section 4.

[24] We note that in the empirical application we have also experimented with a short run variable cost function where equity was treated as a quasi fixed factor, as suggested by Hughes and Mester (1998). Results where almost identical to the those reported here.

the linear approximation is valid. Then, we show how to impose this range on the estimated switching costs.

To derive the valid range for the switching costs parameter, recall the formulas of the transition probabilities, (2.8) and (2.9):

$$\Pr_{i\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} - \bar{p}_{iR,t} - s\right) \tag{3.3}$$

and

$$\Pr_{iR\to i,t} = \alpha_o^i + \alpha_1 \left(p_{i,t} - \bar{p}_{iR,t} + \frac{s}{n-1}\right). \tag{3.4}$$

When switching costs are high, (3.3) approaches unity and (3.4) approaches zero, i.e., most of the customers are effectively locked-in with their former suppliers. For the linear transition probabilities to be valid, they have to lie within the $[0,1]$ interval. The following should, thus, hold:

$$-1 \leq \Pr_{i\to i,t} - \Pr_{iR\to i,t} = -\alpha_1 s \frac{n}{n-1} \leq 1 \tag{3.5}$$

or:

$$\frac{1}{\alpha_1}\frac{n-1}{n} \leq s \leq \frac{1}{-\alpha_1}\frac{n-1}{n}. \tag{3.6}$$

Notice that if, in the estimation process, s is outside the range depicted in (3.6), the estimated equations become meaningless, since it implies negative or larger-than-unity transition probabilities. To impose the valid range on s, define:

$$\overline{s} \equiv \frac{1}{-\alpha_1}\frac{n-1}{n}. \tag{3.7}$$

We would like to restrict s to lie in the interval $[-\overline{s}, \overline{s}]$.[25] Thus, instead of directly estimating s, we estimate a transformation of it, $z \in \Re$ defined by:

$$s \equiv 2\overline{s} \cdot \frac{e^z}{1+e^z} - \overline{s}. \tag{3.8}$$

Note that as $z \to -\infty$, $s \to -\overline{s}$, and as $z \to \infty$, $s \to \overline{s}$. In the estimated equations, we replace s by $2\overline{s} \cdot \frac{e^z}{1+e^z} - \overline{s}$ everywhere.

[25] Actually, n changes slightly over time. Thus, for the constraint to hold in all time periods, the minimal n is applied. In any case, applying different n values is of minor effect, due to the minor variation in n, and since $\partial\frac{n-1}{n}/\partial n \to 0$ for large n (there were $139 - 177$ banks in Norway during that time).

4. Data and Industry Characteristics

4.1. The banking industry

Our data base consists of a panel of annual observations for the Norwegian banking industry, spanning nine years from 1988 to 1996. The panel covers *all* banks operating in Norway in that period.[26] Table D.1 describes the banking industry characteristics.

The number of banks declined from 177 in 1988 to 139 in 1996. The reduction in the number of banks is almost only due to mergers.[27] There is a high cross-sectional variation in bank size, most banks being very small. Figures D.1 and D.2 plot the observations by number of branches, and Figures D.3 and D.4 by market shares, measured by value of loans. It is evident from these figures that the banking industry is characterized by having many very small banks. About 27% (44%) of the observations have only 1 branch (2 or less branches) and 78% have market share smaller than 0.25%. The largest bank in terms of branches has 240. In terms of market shares the largest bank captures 27.4% . The distribution of bank size by both measures is fairly stable throughout the period. The correlation between banks' number of branches and market shares is as high as 0.8775. It is noteworthy to mention, however, that even the very large commercial banks with nationwide branch networks supply loans to the typical small bank customer and to small local businesses. Thus, all banks compete in the market for retail lending.

Table D.1 shows some more important details of the Norwegian banking industry. The growth in bank lending between 1994 and 1996 is associated with the strong recovery of the Norwegian economy after a recession in the late 80's and

[26] The Post bank and several state banks were excluded due to their different nature of business and problematic data.

[27] Most of the mergers are characterized by one relatively large bank (the predator) buying a smaller bank (the prey). We mark customers of the prey as customers that switched to the predator. This treatment implicitly assumes that the predator would have obtained a significant increase in its market share even without the occurrence of the merger. We believe this to be a reasonable assumption.

early 90's. From 1987 to 1993 the average annual growth rate in GDP was just below 2%, whereas the average annual growth rate between 1994 and 1996 was 4.8%. Hence, the increased importance of bank lending at the end of the sample period should be attributed to the relatively strong procyclical pattern of the overall borrowing activity. It follows that to the individual bank this growth may be considered exogenous.

A closer look at the structure of the market for bank loans reveals a relatively stable pattern. The correlations between current market shares and the market shares lagged from one to four years are 0.997, 0.968, 0.935, and 0.927, respectively. These figures may indicate very little switching of borrowers between banks over a one, and even over two year periods.[28]

4.2. Construction of variables

In estimating the cost function, loans extended are treated as bank output.[29] Four variable factors of production are specified: labor, materials, physical capital (machinery and buildings) and funding. The latter includes both deposits and borrowed money, i.e. all bank debt except subordinated debt.[30]

Bank and year specific prices of labor are computed as total labor costs per man-hour. The price of materials is measured by a price index for material inputs to financial institutions, collected from the national accounts statistics. Thus, it varies through time but is constant across banks. That is also the case for the price of physical capital which is proxied by the ten year interest rate on government bonds.

The price of funding is a weighted sum of the interest rate on deposits and the

[28]Strictly speaking, high intertemporal correlation among market shares may also emanate from intensive switching among banks resulting in (close to) zero change in net market shares. However, knowledge of the specific sector makes us believe that there is relatively very little switching.

[29]The output aggregation problem in the context of banking is dealt with in Kim (1986).

[30]Subordinated debt is considered quasi equity, partially being counted as part of the capital base when measuring the capital adequacy according the BIS rules. Only a few banks in our sample have issued subordinated debt.

interest rate on borrowed money. The latter is measured by the three month money market interest rate,[31] thus it only varies across time, not across banks. The interest rate on deposits, however, varies in both dimensions. It is calculated as banks' interest expenditures on deposits divided by the mean of deposits at the beginning and the end of the year.[32] Bank specific interest rates on loans are measured likewise.

The discount factor δ_t applied for estimating the parameters of the first order condition (3.1) is calculated using the 9 to 12 month interest rate on T bills, which amounts to an average of 9.16 per cent in the sample used.

As is seen in the next section we apply a lead and a lag of three years, leaving us with observations only from 1991, 1992 and 1993, and a total of 411 observations in the sample. In these three years the number of banks varied from 147 to 143.

5. Estimation and Results

There are two major issues that have to be attended to in actual estimation. The first relates to the proper length of period before which switching may take place. The second important issue relates to the definition of the industry. To define the industry we have to account for two aspects: (i) customer location preferences and the corresponding banks' branch-network size, and (ii) the ability of banks to provide the entire continuum of loan sizes demanded.

Regarding the first issue, the loan's maturity may help us in deciding on the preferred length of period to be used in the estimation, as we may think of two switching patterns. First, a borrower may terminate the loan agreement and repay the loan to its provider bank whenever sufficiently better loan conditions are offered by a rival bank. Second, a borrower may consider switching to other banks only upon maturity of the loan previously taken. Fixing the model's period equal to

[31] The three month money market interest rate is represented by the three month effective NOK eurorate.

[32] Whenever lagged values of physical capital, loans, deposits, or debt are used to calculate interest rates, the lagged values are adjusted for bank mergers, i.e. the bank structure in period t is imposed on the variables lagged to year $t-1$.

the average length of loans will shed light on the latter switching behavior since in this case borrowers have, on average, one chance to switch between lenders in each period.[33] Using this argument, the model's estimation using shorter period than the average length of loans would involve both switching patterns.

When estimating the model with one and two-year lags, we find out that borrowers hardly switch. Either the estimated switching costs are of such magnitude that the restriction made to ensure the transition probabilities lie in the $[0, 1]$ interval (see (3.8)) was violated (with one-year lag), or (in the two-year lag) the estimated parameters lacked precision.

The intertemporal correlation coefficients between market shares reported in section 4.1 may indicate that there may be more switching of borrowers over a longer time horizon. Given the need for both a lead and a lag of the same length, the longest lag we can use, maintaining the possibility of estimating the whole system simultaneously, is three years.[34] Thus, all our reported results are based on a three year period.

Dealing with the issue of industry definition amounts to deciding which banks should be included in the estimation. This issue is dealt with along both dimensions, that of the branch-network size, and that of loan size. If branch-network size (as is conventionally measured by the number of branches) affects the state and degree of competition, due for instance to location preference, then banks which have very few branches may not correspond well to the model's assumption of mutual competition. As there is no clear and natural cutoff number of branches we estimate the equation system on various size subsamples of banks, defined by different *minimal* number of branches and compare the resulting switching cost estimates. This procedure enables

[33] Degryse and van Cayseele (1998) provide evidence on bank relationship within a bank-based system in Belgium. The average time length of loans in their sample is 2.39 years.

[34] Estimating the system with a four year lag structure produced similar results to the reported three year lag structure. This, however, was feasible only with a two stage (separate) estimation of the cost function and the rest of the system. A joint estimation of the system with a four year lag, and estimation using higher-order lags was not feasible due to the short time dimension of the available data.

us to see whether the various cutoffs result in robust estimates of the switching cost parameters. Table D.2 displays the results of the estimation with subsamples using different *minimal* number of branch cutoffs.

As is apparent from Table D.2, the point estimate of the switching cost estimates range from a low (and insignificant) value of 2.14% for the group consisting of the very large banks (those with 60 or more branches), to a high (and significant) value of 6.87% for the group consisting of banks with 20 or more branches. The point estimate based on the entire sample is 4.12%. We note that all switching cost estimates (except that of the largest group) reported are statistically significant at the 5% level based on a one tailed test.[35] The result that switching cost estimates decrease with bank size may pick up the fact that the larger (branch-network) banks serve a higher proportion of large and mobile (wholesale) customers than smaller retail customers. Large customers are usually publicly traded firms for which asymmetric information problems are relatively less important, and thus the 'lemon' phenomenon is less problematic. Furthermore, larger customers are better at gathering and processing the relevant information in financial markets and therefore are more mobile across banks. This is consistent with Berg and Kim (1998) who document no market power in the market for wholesale loans but strong market power for retail loans.

To verify that the estimates yield valid results, note that the constraint (3.6) is not binding. The point estimate of α_1, the slope of the transition probability functions, ranges from -6.73 for the very large banks to -5.05 for the smaller (less branch intensive) banks. The point estimate for the entire sample is -4.99, all of which are statistically significant at the 1% level. Indeed, in a market with a Bertrand behavior and highly substitutable goods, as is the market for banking loans, the price-cost margin should be very low, as implied by this α_1 estimate.[36]

[35] Switching cost cannot be negative.

[36] As an illustration, the (grand) sample's point estimate of α_1 implies that had switching costs been eliminated (by an exogenous transfer for instance) the average price-cost margin would have been as low as 0.15%. To see that, calculate the price-cost margin in (2.37) for an average size bank.

Recall that the model relies on first-order-approximation of the transition probabilities. Thus, we should check the sensitivity of the switching cost point estimates to the slope of the transition probabilities (α_1). To do so, we re-estimate the equation system, imposing various values (of standard-error deviations from the point estimate) for the slope of the transition probabilities, thereby yielding conditional switching cost estimates. As an illustration we plot these values as a function of the imposed α_1 values for the case of banks with at least 30 branches (36 observations).[37] This is depicted in Figure D.5. The horizontal axis of the figure measures deviations from the point estimate of α_1 (which is -6.35) in standard error units. We also provide 90% and 95% confidence intervals (bounded by the solid lines and the dashed lines, respectively) around the point estimates of the conditional s. It is evident from the figure that the point estimate of the switching cost is not very sensitive to changes in α_1.

In order to further verify that the linear approximation is not the main driving mechanism of the results, we reestimate the equation system on each group of observations, as in Table D.2, imposing various α_1 values around its point estimate. In Figure D.6 we plot the switching costs estimates for these subsamples by *minimal* number of branches, for the different imposed α_1 values and their standard error deviations. This figure shows that the switching costs estimates are rather insensitive to variation in the values of α_1. The only large deviation occurs when the equation system is estimated on the 10- and 20- branches cutoff samples, and α_1 is restricted to be two standard errors larger than its unrestricted value.

The second important aspect of industry definition is loan size. Specifically, small banks have very low lending capacity resulting in loans of very small sizes whereas large banks have high lending capacity resulting in the provision of the entire continuum of loan quantity demanded. This results in different mix of customers

[37] In what follows we present this exercise for each of the groups in a combined figure (see Figure D.6).

served by the various banks. Thus, relatively large customers (usually firms) will find it impossible to switch to small banks which do not have the capacity to serve them. This may have the effect of introducing very large and perhaps pathological switching costs in the case of very small banks which, in turn may result in quite a large point estimate for the average switching cost when estimation is carried out on the entire sample of banks. Since our data set does not provide information on the customer mix we have estimated our system of equations on various size subsample, defined by the *minimal* total loan-size.[38] The results are presented in Table D.3 and, for expositional purpose, are also depicted in Figure D.7. The switching cost parameter estimates range from as low, and statistically insignificant, a value of 0.21% for the group consisting of the largest banks (those with loans over 12 bill. NOK) to, as high and statistically significant, a value of 8.44% for the group consisting also of the smaller banks. These results should be juxtaposed on the point estimate based on the entire sample (4.12%, which was discussed earlier). The general pattern here is very similar to the one present when estimation was based on the size of the branch network. This should not come as a surprise as the correlation between size of banks measured by the branch network size and size of loans is quite high (0.8775 for the entire sample). As we did for the estimation on subsamples by minimal number of branches, we check the sensitivity of the switching cost estimates to the slope of the transition probability. In Figure D.8 we plot the switching costs estimates for subsamples by loan size, for different imposed α_1 values and their standard error deviations. As before, the various switching cost estimates are insensitive to variations in α_1. Large deviations occur only when the equation system is estimated on observations with loans of at least 2 bil. NOK when α_1 is restricted to be one standard error larger than its unrestricted value and on observations with loans of at least 4 bil. NOK when α_1 is restricted to be two standard errors larger than its

[38] The reason for the various cut off points is the compatibility with those applied to the number of branches in terms of number of observations.

unrestricted value.

We reiterate that the estimated switching costs described above capture not only the direct pecuniary effect but also the various psychological aspects of switching, as well as the indirect, and perhaps the most important, economic costs associated with the loss of the capitalized value of long-term customer bank relationship. One major aspect contributing to the relatively high switching cost estimates is the one related to the downturn of the economy resulting in system wide banking problems which exacerbated the 'lemon' problem and hence the reluctance of banks to provide loans to new customers.[39] The other major aspect has to do with the long duration of bank-customer relationship documented in American, and European banking.

5.1. Counterfactuals

The parameter estimates reported in the previous section can be used to derive and extract a host of interesting quantitative information regarding the effects of switching costs on both borrowers' and banks' characteristics. In what follows we present and discuss characteristics such as: (i) the average duration of contact between a bank and its borrowers, (ii) the probability of staying with a particular bank vs. that of switching, (iii) the contribution of previous periods' market shares to the current ones, and (iv) the contribution of the "lock-in" phenomenon to banks' marginal profits.

Inserting the (total sample) estimates of α_1 and s into (3.5) we find that the probability that an existing customer will continue to purchase from the firm is larger than the probability that a rival's customer will switch to the firm, by 20%. A closer look at this probability when markets are defined according to the size of the branch network generates a range of $17\% - 32\%$, which averages 30%. Defining the market according to loan-size, this range is between $2\% - 43\%$ with an average

[39] It should be noted, however, that during the problematic period ($1990 - 1993$) only one small bank was actually closed. All other banks that got into problems were able to continue their lending operations due to government interventions.

of 35% (see sixth column in Table D.4).[40]

For the average bank, we may assess the transition probabilities (2.12) and (2.13)[41]:

$$\widehat{\underset{i \to i,t}{\mathrm{Pr}}} = \overline{\alpha}_o^i + \widehat{\alpha}_1 \left(p_{i,t} - \bar{p}_{iR,t} - \widehat{s} \right). \tag{5.1}$$

and

$$\widehat{\underset{iR \to i,t}{\mathrm{Pr}}} = \overline{\alpha}_o^i + \widehat{\alpha}_1 \left(p_{i,t} - \bar{p}_{iR,t} + \frac{\widehat{s}}{n-1} \right). \tag{5.2}$$

where $\overline{\alpha}_o^i = 1/n$. The estimated probabilities in (5.1) and (5.2) indicate that after one year 40% of the average bank's customers switch to other banks. Recall that the transition probabilities are based on a three-year period. We annualize these probabilities as follows: $\theta = 1 - (\widehat{\mathrm{Pr}_{i \to i,t}})^{1/3} = 0.40$ where θ is the annual defection rate (last column in Table D.4). Of course, these estimates are based on the total sample. Using the various market definitions, as above, we get similar results but realize that for the larger banks the $\widehat{\mathrm{Pr}_{i \to i,t}}$ are of smaller magnitude. This is consistent with the fact that larger banks have higher proportion of wholesale customers over which market power is indeed minimal, see Berg and Kim (1998). The turnover period (the average duration of customer-bank relationship) is thus, $3 \div (1 - 0.213) = 3.812$ years. Turnover calculations however, are somewhat misleading since, in fact, some of the bank's customers may never switch. Thus, in addition to the turnover period, we may calculate the time required for k percent of the customers to switch. Denoting this time period by $\lambda = \ln(1-k) \div \ln(1-0.40)$, for $k = 99\%$, $\lambda = 8.9$ years. Again, these calculations are based on the estimation using the entire sample observations. However, as was demonstrated, results are somewhat different when estimation is carried out on different subsamples according to branch network size or output size. The range of customer-bank relationship is between 11.3 and 16.7 years with an average of 13.6 years if markets are defined by branch-network-size, or

[40] Note that eq. (3.5) = eq. (2.15).

[41] Hats ($\widehat{\ }$) denote estimates.

between 7.5 and 19.4 years with an average of 13.5 years if the definition is according to loan-size. The interesting point though is the general pattern that the duration of relationship is smaller for the large banks (7.5 years for those with loans over 12 billion NOK, see Table D.4), again consistent with Berg and Kim (1998).

Our finding is very much in line with recent literature on relationship lending within a bank-based system using detailed (survey) micro data. Ongena and Smith (1998) use panel data of connections between Oslo Stock Exchange-listed firms and their banks, for the 1979-1995 period. After correcting for censoring bias, the estimated mean duration of firm-bank relationship varies between 15 and 18 years. This is also in line with other studies using European and American survey data. Angelini, Di Salvo, and Ferri (1997) report an average duration of 14 years for Italy. Cole (1998) finds mean duration of US firms (based on data from the National Survey of Small Business Finance) to be 7 years. Harhoff and Körting (1997) report average duration of 13 years for German firms. Petersen and Rajan (1994) report an 11 years mean duration in the US. Degryse and van Cayseele (1998) report a mean value for the length of bank relationship in Belgium of 7.8 years.

The estimated parameters also suggest (sixth column of Table D.4) that the contribution of the previous period's market share to the current one, as defined by (2.16) is 0.2 when considering the entire sample. This means that about 20% of the average bank's market share is due to its bank-borrower relationship in the previous period. This however, can be as low as 17% and 0.2% for the very large banks when the market is defined by the branch network-size and by the loan-size respectively. When smaller banks are also included it is 32% and 42% respectively. Again, this points to the higher mobility of (larger) customers working with larger banks where output is characterized by a higher proportion of wholesale loans.

An interesting and important issue is that of the proportion of the marginal value of a locked-in customer ($mvl_{i,t}$) to the marginal increase of the bank's present value which is due to an additional locked-in customer ($\partial V_{i,t}/\partial y_{i,t}$), as in (2.39).

Based on the total sample, the value of $mvl_{i,t}/(\partial V_{i,t}/\partial y_{i,t})$ is 0.16, that is 16% of the customer's added value is attributed to the lock-in phenomenon generated by switching costs. We note however, that a similar pattern emerges here as it did with the other characteristics considered, namely, the contribution of locked-in customers to banks' value decrease as the size of bank increases. Specifically, as is apparent from Table D.4, the contribution of locked-in customers to banks' value ranges from a low of 13% for the very large banks to 30% for the group including also the smaller ones when the market is defined according to branch-network-size. It is more pronounced when considering loan-size as the definition of the market, where locked-in customers contribute only 1% in the case of the large banks, and 32% in the case of the smaller banks. Once more, these results emanate from the higher proportion of mobile wholesale customers of larger banks. It is noted that on the average (for either definition of the market) the locked-in customers contribute 23% to banks' value.

6. Concluding Remarks

In the present paper we present an empirical model of firms' strategic behavior in the presence of switching costs. Customers' transition probabilities embedded in firms strategic interaction are used in a multi-period model to derive estimable equations of a first order condition and market-share (demand) equations. The novelty of the model is in its ability to extract information on both the magnitude and significance of switching costs, as well as on customers' transition probabilities, from conventionally available highly aggregated data which do not contain customer-specific information. As a matter of illustration, the model is applied to panel data of banks, to estimate the switching costs in the market for bank loans. We find that the grand sample point estimate of switching costs is about 4.1% and can be as low as 0.2% when only banks with the largest loan portfolio are included in the definition of the market. When the market is defined according to the branch-network-size the switching cost among the largest banks is about 2.1% . We find that on the average 23.0% of the customer's added value is attributed to the lock-in phenomenon generated by this switching cost. As much as an average of 35.0% of the average bank's market share is due to its established bank-borrower relationship. The model estimates imply an average of 13.5 years average duration of bank-customer relationship. All the above characteristics exhibit lower values for the group of larger banks whose loan portfolio is dominated by more mobile wholesale customers.

To summarize, switching costs in the market for bank loans are quite substantial and constitute a significant portion of the value of a marginal customer to the average firm. The presented technique may be applied to other markets in order to gain insight into the empirical regularity of switching costs.

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A. The Case of Noisy Prices

Denote the firm's true price by $p^*_{i,t}$, and rivals' true price average by $\bar{p}^*_{iR,t}$. The probability that firm i's customer will continue to purchase from it then becomes:

$$\Pr_{i\to i,t} = A^i_o + \alpha_1 p^*_{i,t} + \alpha_2 \left(\bar{p}^*_{iR,t} + s\right). \tag{A.1}$$

The firm's and the rivals' *observed* prices equal the true prices plus error terms:[42]

$$p_{i,t} = p^*_{i,t} + \xi_i \tag{A.2}$$

and:

$$p_{j,t} = p^*_{j,t} + \xi_j. \tag{A.3}$$

When inserting the true prices into the transition probability function all error terms are captured by the intercept, and no effect on α_1, α_2 and s remains:

$$\begin{aligned} \Pr_{i\to i,t} &= A^i_o + \alpha_1 p^*_{i,t} + \alpha_2 \left(\bar{p}^*_{iR,t} + s\right) \\ &= A^i_o + \alpha_1 \left(p_{i,t} + \xi_i\right) + \alpha_2 \left(\bar{p}_{iR,t} + \overline{\xi}_{iR} + s\right) \end{aligned} \tag{A.4}$$

where $\bar{p}^*_{iR,t}$ and $\overline{\xi}_{iR}$ are the average of rivals' prices and error terms, respectively. The transition probability then becomes (2.8), where $\alpha^i_o = A^i_o + \alpha_1\xi_i + \alpha_2\overline{\xi}_{iR}$. The same applies to $\Pr_{iR\to i,t}$ in (2.9).

[42] notice that the error terms may have any specific mean or variance.

B. The Cost Function

Bank i's time-variant cost function is represented by its second-order Taylor-series approximation of the following form:

$$\begin{aligned}\ln c_{i,t} = {} & \gamma_0 + \gamma_y \ln y_{i,t} + \sum_k \gamma_k \ln w_{k,i,t} \\ & + \frac{1}{2}\left(\sum_k \sum_l \gamma_{kl} \ln w_{k,i,t} \ln w_{l,i,t} + \gamma_{yy} \left(\ln y_{i,t}\right)^2\right) \\ & + \sum_k \gamma_{ky} \ln w_{k,i,t} \ln y_{i,t} \end{aligned} \tag{B.1}$$

Application of Shepherd's lemma to (B.1) yields the following factor demand (share) equations:

$$\frac{\partial \ln c_{i,t}}{\partial \ln w_{k,i,t}} \equiv m_{k,i,t} = \gamma_k + \sum_l \gamma_{k,l} \ln w_{l,i,t} + \gamma_{ky} \ln y_{i,t} \tag{B.2}$$

where $m_{k,i,t}$ is the share of the k^{th} factor in bank i's period-t production cost. The following restrictions for symmetry and linear homogeneity in prices are imposed on the cost (production) structure,

$$\gamma_{kl} = \gamma_{lk}, \quad \forall k, l; \; \sum_k \gamma_k = 1; \; \sum_k \gamma_{ky} = 0; \; \sum_l \gamma_{kl} = 0, \quad \forall k. \tag{B.3}$$

Marginal production cost estimates are obtained from (B.1):[43]

$$mc_{i,t} \equiv \frac{\partial c_{i,t}}{\partial y_{i,t}} = \frac{c_{i,t}}{y_{i,t}} \left(\gamma_y + \gamma_{yy} \ln y_{i,t} + \sum_k \gamma_{ky} \ln w_{k,i,t}\right) \tag{B.4}$$

and is inserted in the first order condition (3.1) in the text.

[43] Due to Shephard's Lemma, one of the input share equations is omitted to ensure non-singularity as shown in the appendix.

C. Differentiating the Firm's Output

The demand faced by the firm, after substituting the linear transition probabilities is:

$$y_{i,t} = \begin{pmatrix} y_{i,t-1}\left(\alpha_o^i + \alpha_1\left(p_{i,t} - \bar{p}_{iR,t} - s\right)\right) \\ +y_{iR,t-1}\left(\alpha_o^i + \alpha_1\left(p_{i,t} - \bar{p}_{iR,t} + \frac{s}{n-1}\right)\right) \end{pmatrix} g_t \tag{C.1}$$

or:

$$y_{i,t} = \left(-y_{i,t-1}\frac{n}{n-1}s\alpha_1 + y_{t-1}\alpha_o^i + y_{t-1}\alpha_1\left(p_{i,t} - \bar{p}_{iR,t} + \frac{s}{n-1}\right)\right) g_t. \tag{C.2}$$

Differentiating w.r.t. the firm's price and rivals' average price:

$$\frac{\partial y_{i,t}}{\partial p_{i,t}} = y_{t-1}\alpha_1 g_t \tag{C.3}$$

and:

$$\frac{\partial y_{i,t}}{\partial \bar{p}_{iR,t}} = -y_{t-1}\alpha_1 g_t. \tag{C.4}$$

The time $t+1$ demand is:

$$y_{i,t+1} = \left(-y_{i,t}\frac{n}{n-1}s\alpha_1 + y_t\alpha_o^i + y_t\alpha_1\left(p_{i,t+1} - \bar{p}_{iR,t+1} + \frac{s}{n-1}\right)\right) g_{t+1}. \tag{C.5}$$

Differentiating w.r.t. the firm's time $t+1$ price and rivals' time $t+1$ average price:

$$\frac{\partial y_{i,t+1}}{\partial p_{i,t}} = -\frac{\partial y_{i,t}}{\partial p_{i,t}}\frac{n}{n-1}s\alpha_1 g_{t+1} = -y_{t-1}\alpha_1\frac{n}{n-1}s\alpha_1 g_t g_{t+1} \tag{C.6}$$

and:

$$\frac{\partial y_{i,t+1}}{\partial p_{i,t+1}} = y_{t-1}\alpha_1 g_t g_{t+1}. \tag{C.7}$$

D. Tables and Figures

Table D.1: Industry characteristics

	1988	1989	1990	1991	1992	1993	1994	1995	1996
No. of banks	177	168	155	147	145	143	141	140	139
No. of branches:									
– mean	12	12	12	11	11	11	11	11	11
– max	160	141	240	205	193	182	182	194	183
Bank Loans (bil. NOK)	423	456	473	444	443	453	471	512	580
Loans per bank (bil. NOK):									
– mean	2.38	2.71	3.05	3.02	3.06	3.17	3.34	3.66	4.17
– std. dev.	8.16	9.46	13.44	12.50	12.65	11.92	11.98	12.94	14.82
Equity per bank (bil. NOK):									
– mean	0.13	0.15	0.15	0.11	0.13	0.23	0.29	0.34	0.38
– std. dev.	0.45	0.56	0.61	0.28	0.23	0.66	1.01	1.17	1.34
Assets per bank (bil. NOK):									
– mean	3.24	3.56	3.93	3.86	4.00	4.02	4.19	4.44	5.21
– std. dev.	11.43	12.60	17.49	16.15	17.17	15.69	15.74	16.14	19.48
Interest rate (pct.):									
– mean	16.07	14.82	14.15	13.72	13.23	10.99	8.47	8.11	7.50
– std. dev.	1.32	0.89	0.79	0.69	1.38	0.69	0.57	0.48	0.48
T bond rate (pct.)	12.88	10.86	10.86	9.99	9.62	6.86	7.46	7.43	6.78

Bank loans include all domestic loans extended by all banks in the sample. Interest rate is the calculated interest rate on loans extended by the banks in the sample. See section 4.2 for calculation details.

Table D.2: Switching costs subsamples by minimal number of branches, parameter estimates.

Min. no. of branches:	1*	10	20	30	40	50	60
γ_l (output)	0.989 (0.007)	0.919 (0.009)	0.919 (0.010)	0.915 (0.011)	0.899 (0.012)	0.891 (0.016)	0.785 (0.023)
γ_w (labor)	0.139 (0.002)	0.149 (0.002)	0.150 (0.003)	0.148 (0.003)	0.145 (0.003)	0.147 (0.003)	0.145 (0.003)
γ_k (capital)	0.018 (0.001)	0.014 (0.001)	0.013 (0.002)	0.013 (0.005)	0.014 (0.001)	0.014 (0.005)	0.014 (0.001)
γ_f (funding)	0.720 (0.003)	0.708 (0.004)	0.709 (0.005)	0.710 (0.005)	0.714 (0.016)	0.715 (0.005)	0.718 (0.005)
α_1 (trans. prob. slope)	-4.994 (0.786)	-5.043 (0.939)	-5.391 (1.176)	-6.352 (0.965)	-6.711 (0.996)	-6.670 (1.248)	-6.727 (0.878)
s (switching cost, pct.)	4.120 (2.164)	6.040 (2.747)	6.867 (3.114)	3.361 (1.848)	2.892 (1.665)	4.423 (2.321)	2.142 (1.598)
no. of obs.	411	61	45	36	30	27	20

The table reports parameter estimates and goodness-of-fit statistics for the jointly estimated equation system consisting of equations (3.1), (3.4), (A.1) and (A.2). Standard errors (in parentheses) are White (1980) heteroschedasticity-adjusted. (*) indicates total sample. Second order terms of the cost function are not reported for brevity of exposition.

Table D.3: Switching costs subsamples by loan size, parameter estimates.

Min. Loans (bill.):	$> 0^*$	2	3	4	5.5	7.5	12
γ_l (output)	0.989 (0.007)	0.946 (0.013)	0.944 (0.012)	0.942 (0.013)	0.930 (0.012)	0.925 (0.016)	0.748 (0.020)
γ_w (labor)	0.139 (0.002)	0.148 (0.002)	0.149 (0.002)	0.149 (0.003)	0.147 (0.002)	0.146 (0.003)	0.146 (0.003)
γ_k (capital)	0.018 (0.001)	0.014 (0.002)	0.014 (0.001)	0.014 (0.001)	0.014 (0.001)	0.015 (0.002)	0.015 (0.001)
γ_f (funding)	0.720 (0.003)	0.715 (0.005)	0.714 (0.005)	0.713 (0.005)	0.713 (0.005)	0.715 (0.005)	0.717 (0.005)
α_1 (trans. prob. slope)	−4.994 (0.786)	−4.699 (1.233)	−5.551 (1.235)	−5.838 (1.341)	−6.748 (1.166)	−6.725 (1.490)	−6.679 (0.728)
s (switching cost, pct.)	4.120 (2.164)	8.437 (4.363)	6.341 (3.156)	6.270 (3.279)	4.121 (2.089)	5.690 (2.948)	0.213 (1.309)
no. of obs.	411	55	48	42	36	28	21

The table reports parameter estimates and goodness-of-fit statistics for the jointly estimated equation system consisting of equations (3.1), (3.4), (A.1) and (A.2). Standard errors (in paremtheses) are White (1980) heteroschedasticity-adjusted. (*) indicates total sample. Second order terms of the cost function are not reported for brevity of exposition.

Table D.4: Characteristics by subsamples.

Characteristic:		no. obs.	$\widehat{\Pr}_{i\to i,t}$	$\widehat{\Pr}_{iR\to i,t}$	$\lambda_{k=0.99}$	$\frac{\partial\sigma_{i,t}}{\partial\sigma_{i,t-1}}$	$\frac{mvl_{i,t}}{\partial V_{i,t}/\partial y_{i,t}}$	θ
Mkt. definition								
By branch:								
	10	61	0.35	0.03	13.3	0.32	0.25	0.29
	20	45	0.44	0.04	16.7	0.40	0.30	0.24
	30	36	0.30	0.06	11.4	0.24	0.18	0.33
	40	30	0.29	0.08	11.3	0.21	0.17	0.33
	50	27	0.41	0.07	15.3	0.34	0.26	0.26
	60	20	0.29	0.12	11.3	0.17	0.13	0.34
Average:			0.35	0.05	13.6	0.30	0.23	0.30
By loan size:								
	2	55	0.45	0.03	17.3	0.42	0.32	0.23
	3	48	0.41	0.04	15.7	0.37	0.29	0.25
	4	42	0.44	0.04	16.7	0.40	0.30	0.24
	5.5	36	0.36	0.06	13.6	0.30	0.23	0.29
	7.5	28	0.49	0.06	19.4	0.43	0.33	0.21
	12	21	0.16	0.14	7.50	0.02	0.01	0.46
Average:			0.38	0.03	13.48	0.35	0.23	0.28
Total sample:		411	0.21	0.01	8.90	0.20	0.16	0.40

$\lambda_{k=0.99}$ represents the duration of relationship based on the time required for $k\%$ of the customers to switch. $\frac{\partial\sigma_{i,t}}{\partial\sigma_{i,t-1}}$ represents the contribution of the $t-1$ market share to the market share in period t. The term $\frac{mvl_{i,t}}{\partial V_{i,t}/\partial y_{i,t}}$ represents the proportion of the marginal value of locked-in customer in the marginal increase in the bank's present value. The θ is annual defection rate.

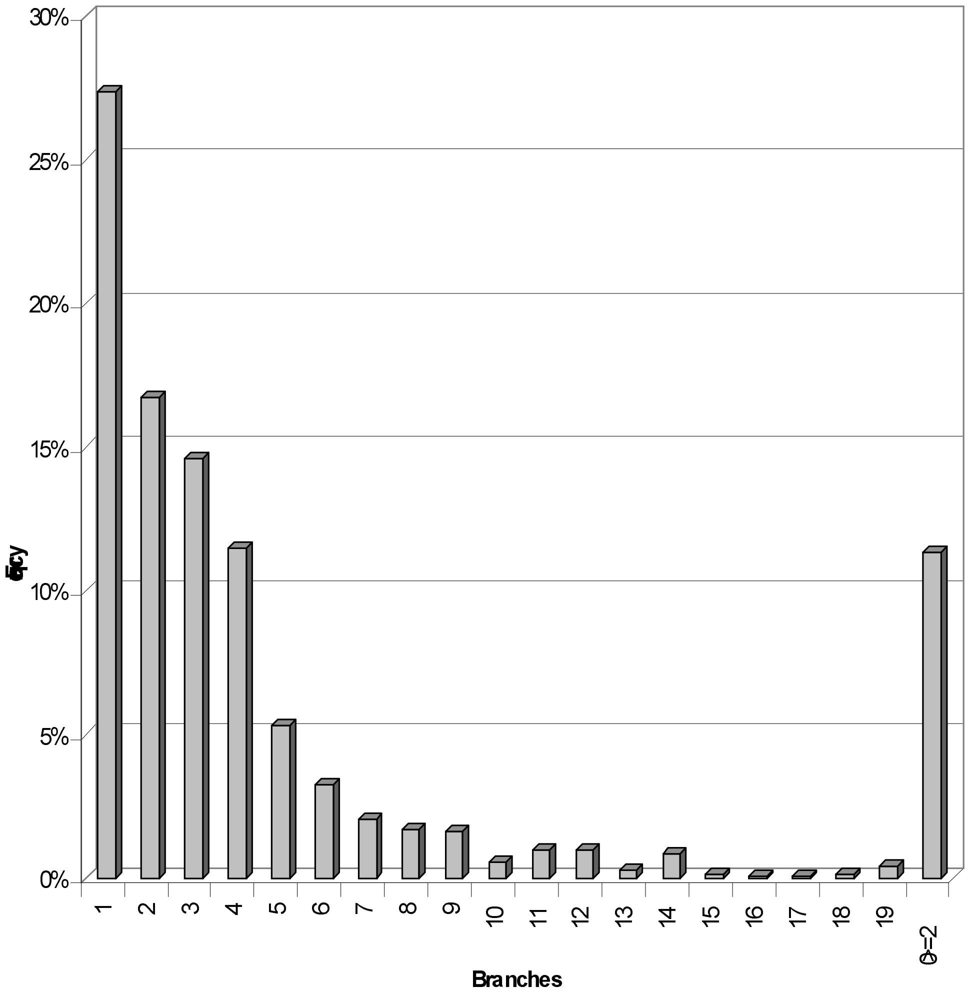
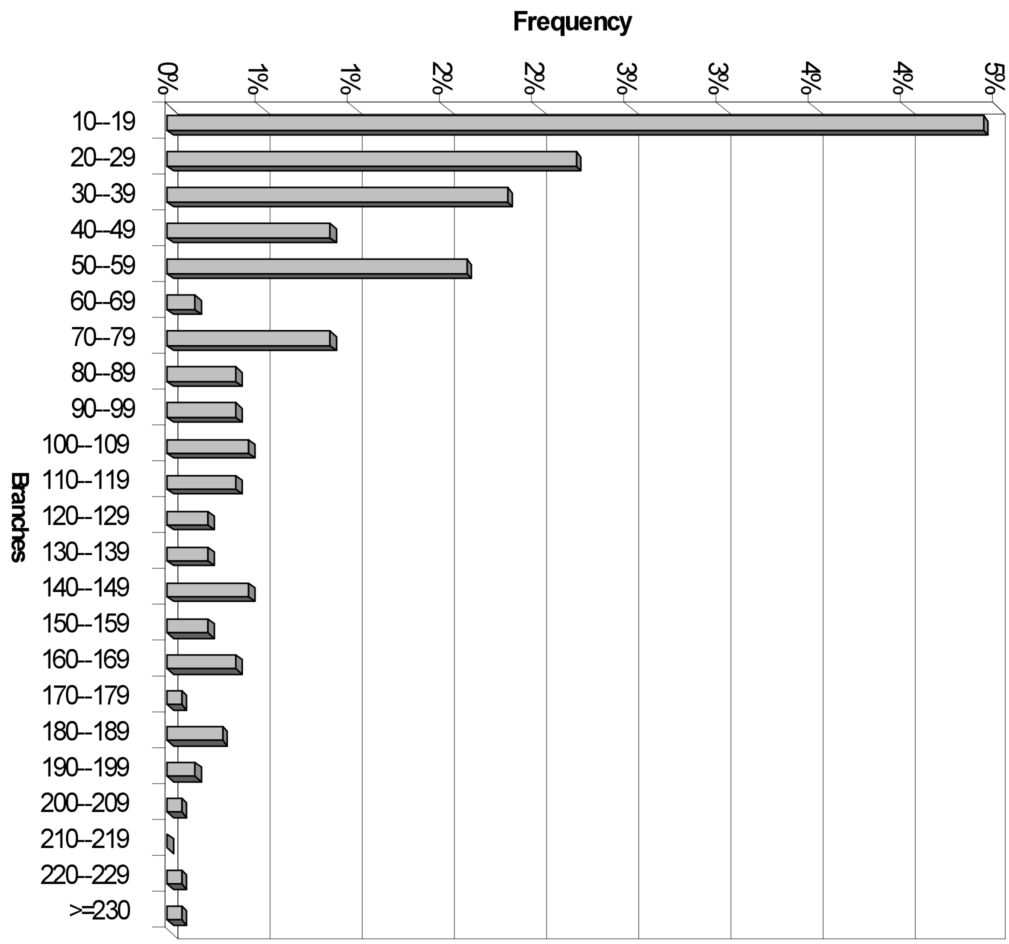
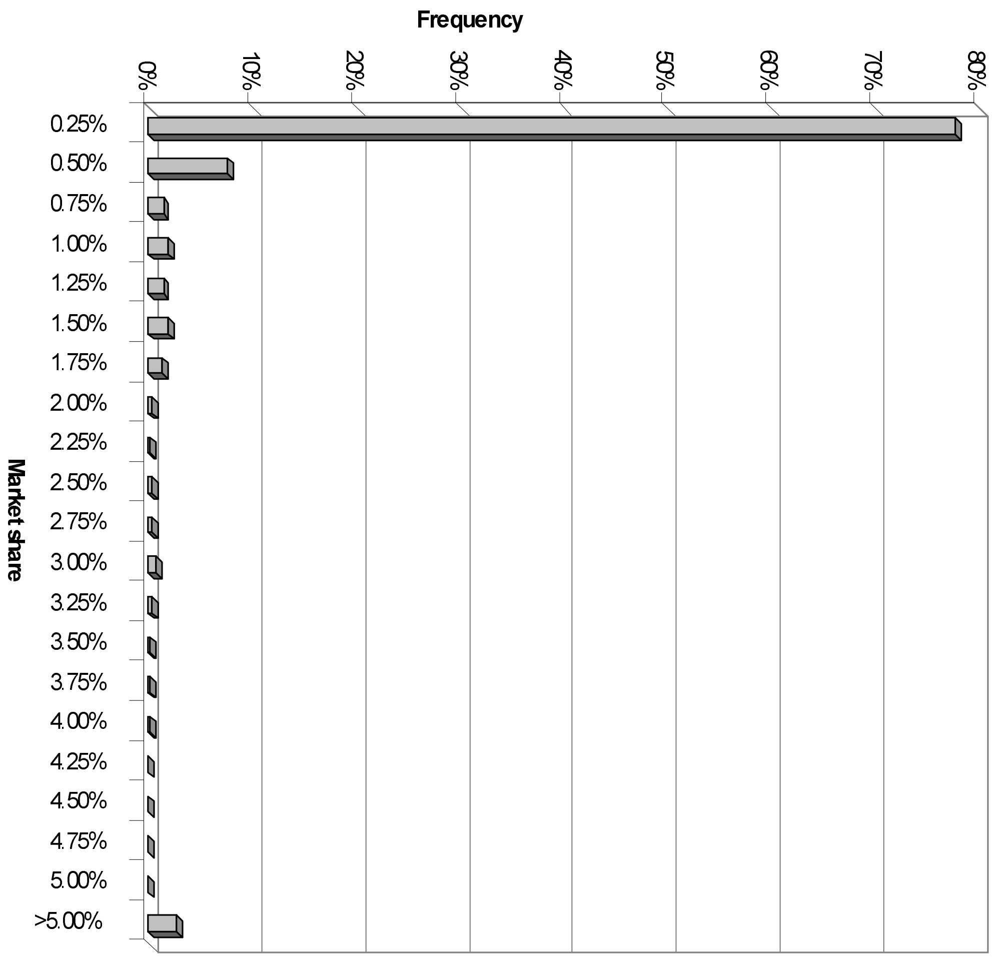
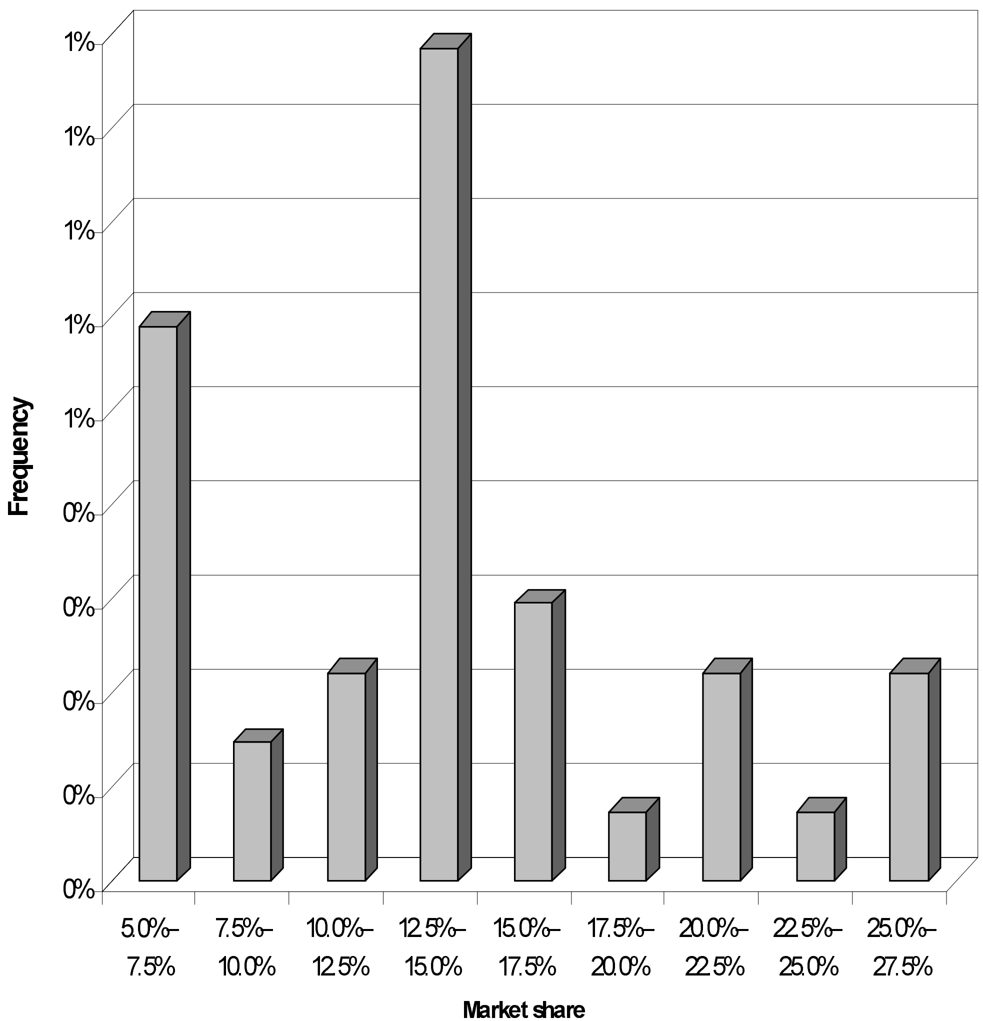


Figure D.1: Sample distribution by number of branches.



Frequency
0%
1%
1%
2%
2%
3%
3%
4%
4%
5%
Branches
10--19
20--29
30--39
40--49
50--59
60--69
70--79
80--89
90--99
100--109
110--119
120--129
130--139
140--149
150--159
160--169
170--179
180--189
190--199
200--209
210--219
220--229
>=230


Frequency
0%
10%
20%
30%
40%
50%
60%
70%
80%
Market share
0.25%
0.50%
0.75%
1.00%
1.25%
1.50%
1.75%
2.00%
2.25%
2.50%
2.75%
3.00%
3.25%
3.50%
3.75%
4.00%
4.25%
4.50%
4.75%
5.00%
>5.00%


Frequency
1%
1%
1%
1%
1%
0%
0%
0%
0%
0%
5.0%–7.5%
7.5%–10.0%
10.0%–12.5%
12.5%–15.0%
15.0%–17.5%
17.5%–20.0%
20.0%–22.5%
22.5%–25.0%
25.0%–27.5%
Market share

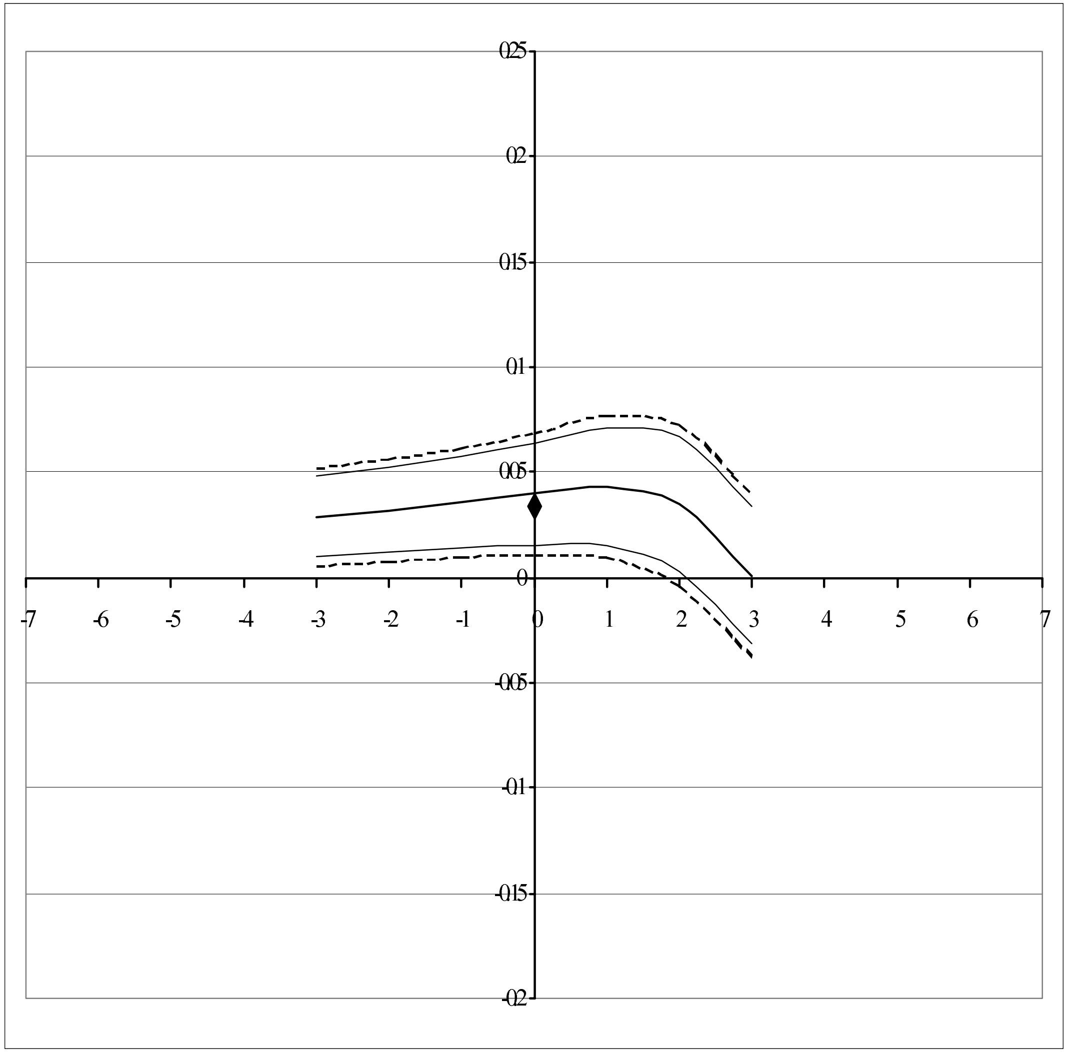


Figure D.5: Switching costs estimates for the subsample of observations with at

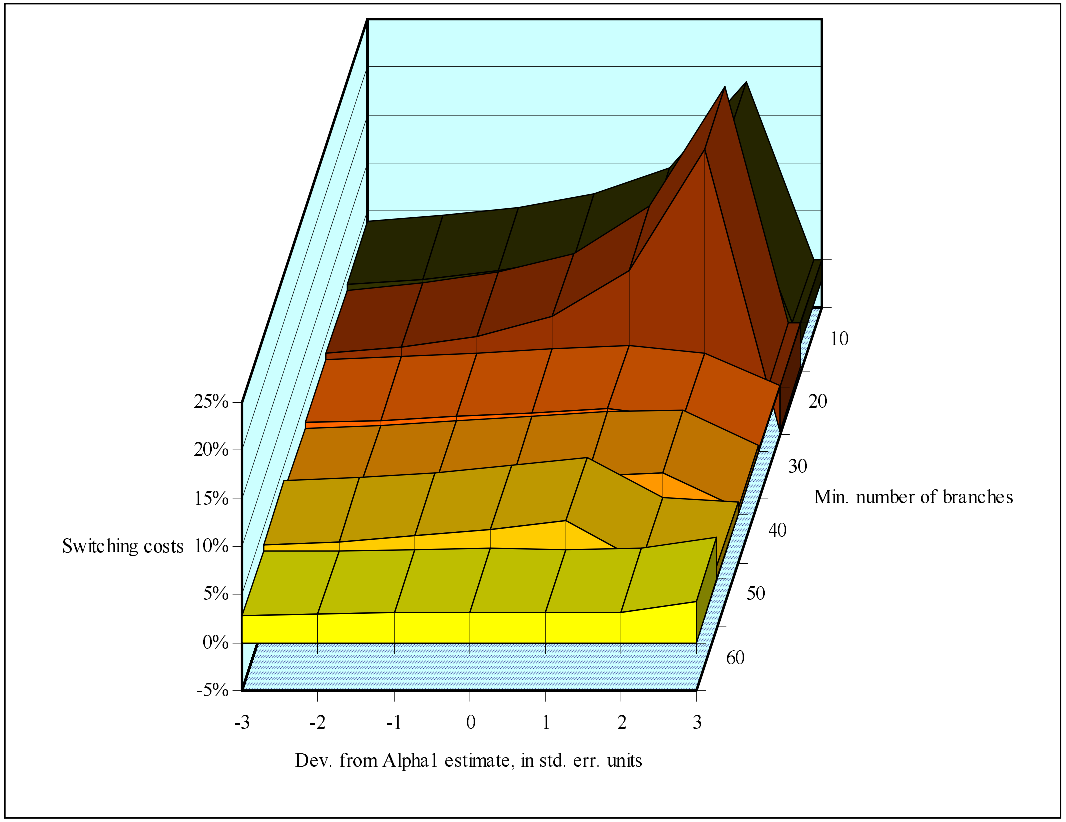
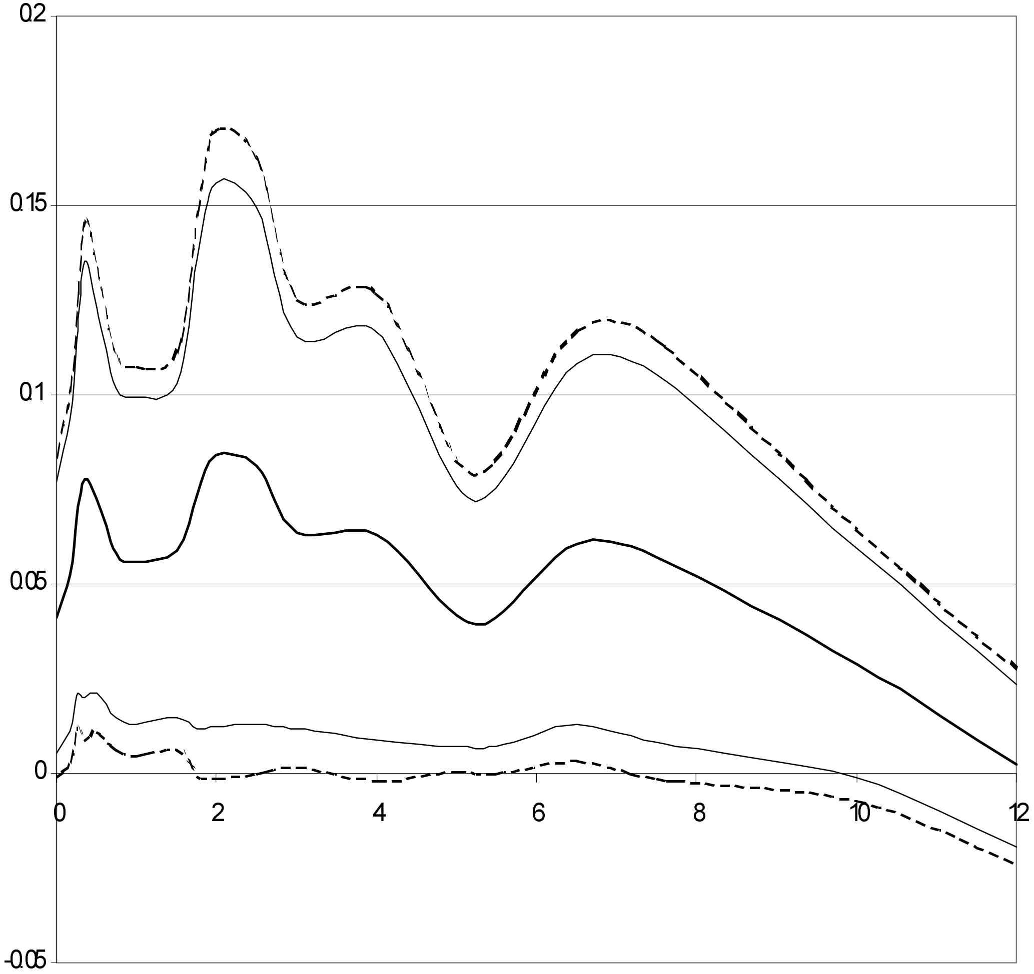


Figure D.6: Switching costs estimates for subsamples by minimum number of branches, with restricted α_1 values.



0.2
0.15
0.1
0.05
0
-0.05
0
2
4
6
8
10
12

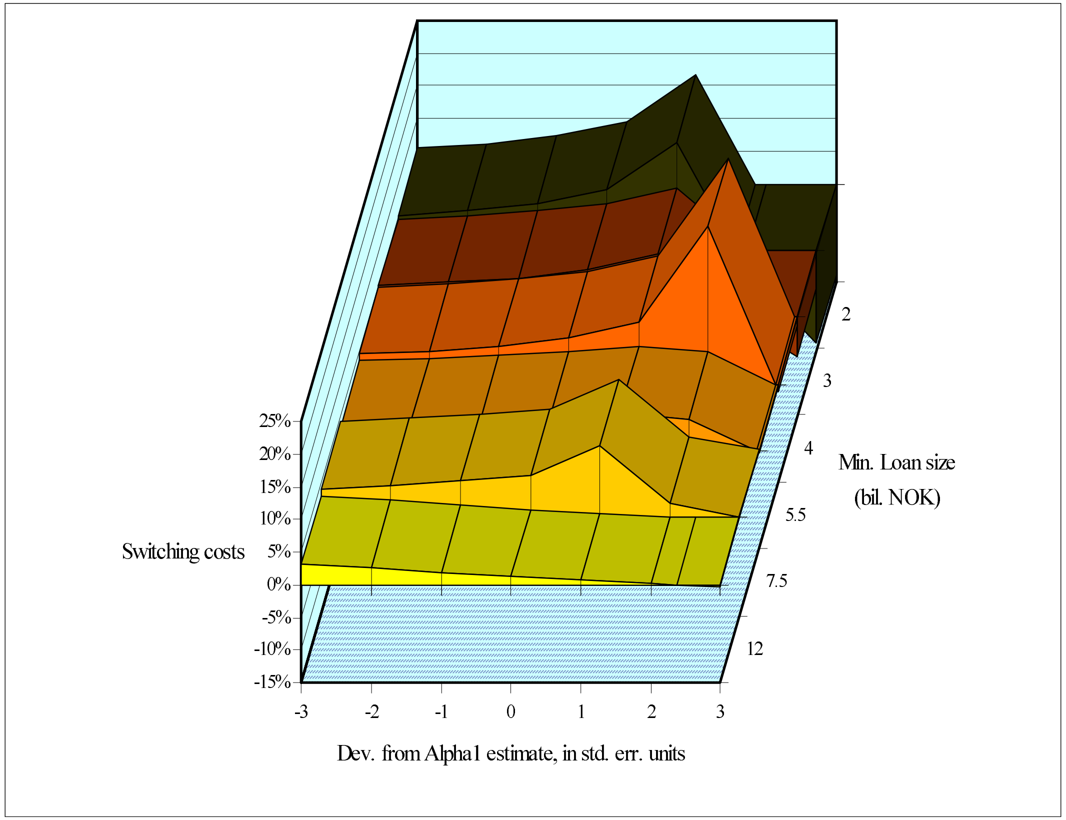


Figure D.8: Switching costs estimates for subsamples by minimum loan size, with restricted α_1 values.